# Overview of IS PI Workshop in Automated Reasoning September 4-6, 2002

Robert Morris
NASA Ames Research Center
Computational Sciences Division

AR Manager: Robert Morris, ARC
Deputy Manager: Ben Smith, JPL
Level 4 Managers: Mike Lowry, John Bresina, ARC

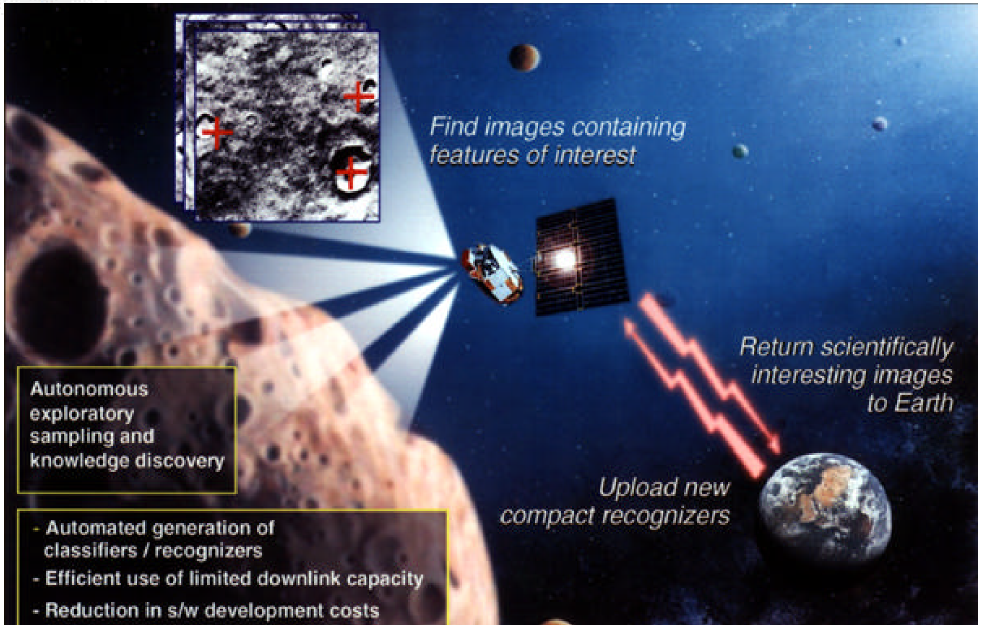
# *Intelligent Systems Program/Automated Reasoning Element*

- **Research and develop component capabilities for autonomy**
  - Identify architecture for autonomous systems
  - Leverage existing methods to develop computational solutions to hard research challenges
- **Integrate autonomy components**
  - Real-world testing in real or simulated environment
- **Support mission insertion of autonomy**
  - Supply funding for mission insertion development
  - Determine that the software will work correctly and within mission constraints
  - Help make it cost-effective to produce, maintain, and reuse the software

# Automated Reasoning Sub-elements

- Intelligent Sensing and Reflexive Behavior
- Planning and Execution
- Model-based Fault Protection
- Distributed Autonomy and Architectures
- Automated Software Engineering for Autonomy

# Intelligent Sensing and Reflexive Behavior




- Develop systems with situational awareness
  - Respond to external threats to system
  - Adapt to changes in environment and device
- Emphasis on reactivity, not deliberation.

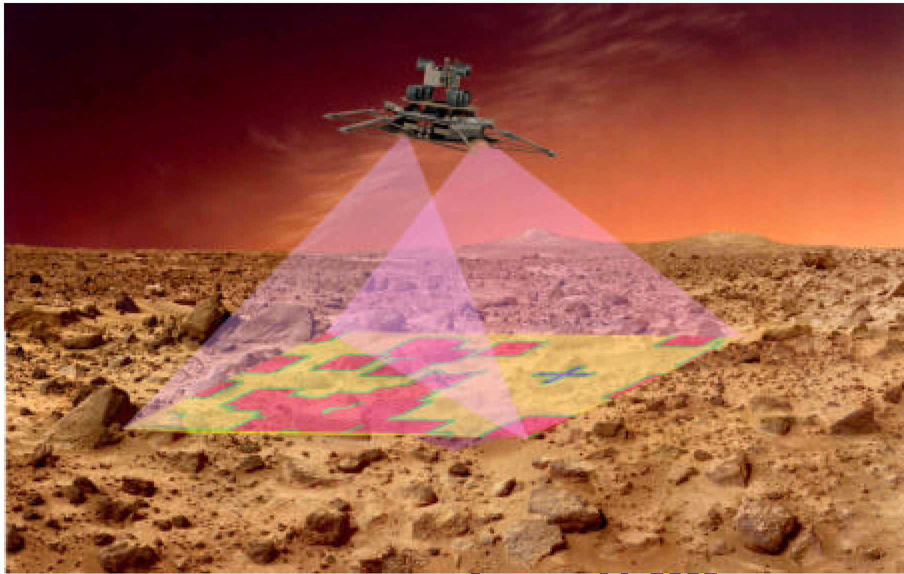
Research challenges:

*Traverse Science*

***Detect geologic science opportunities in a Mars-rover context and generate plans for follow-up investigation***

*Safe & Precise Landing*

***Fast machine vision algorithms that estimate lander position & pose and find safe, high science-value sites.***



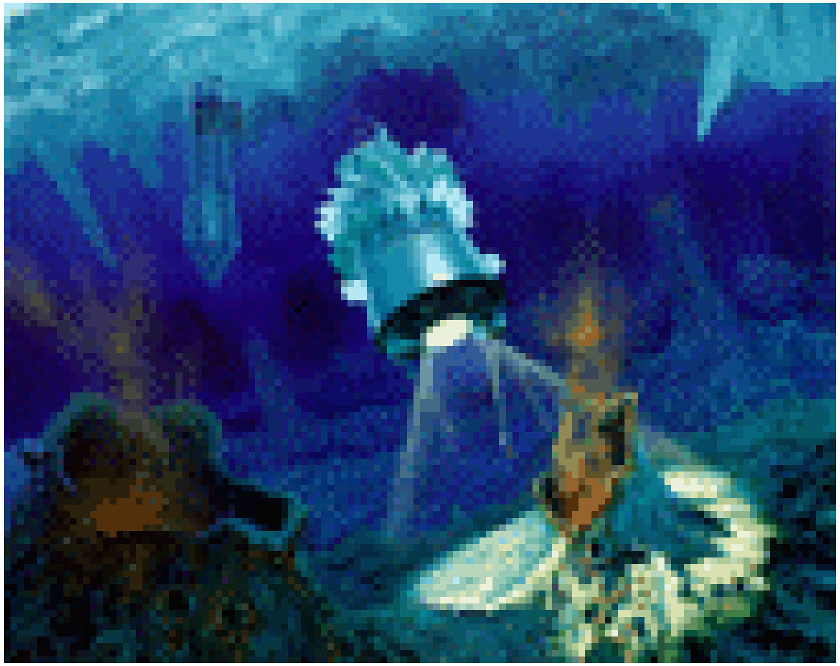
# Project Summaries: Intelligent Sensing and Reflexive Behavior 4-4-02

| | | | | |
|---|---|---|---|---|
| | 1100 | James Montgomery | JPL | Vision-Guided Landing |
| | 1115 | Peter Cheeseman | ARC/RIACS | Super-Resolved Images |
| | 1130 | Robert W. Mah | ARC | Neurocontrol for Shuttle Docking |
| | 1145 | Greg A. Dorais | ARC | Spacecraft Micro Robot |

# Planning & Execution

•Develop automated planning systems for decomposing high level goals into sequences of activities that satisfy temporal, resource, and other constraints.

•Develop systems for robust execution of command sequences while monitoring and responding to system failures



**Research Challenges:**

•*Planning effectively with time & resources*

•*Mixed initiative mission optimization planning*

•*Planning and reasoning in uncertain environments*

•*Real time planning and execution*

# Project Summaries: Planning and Execution 4-04-02

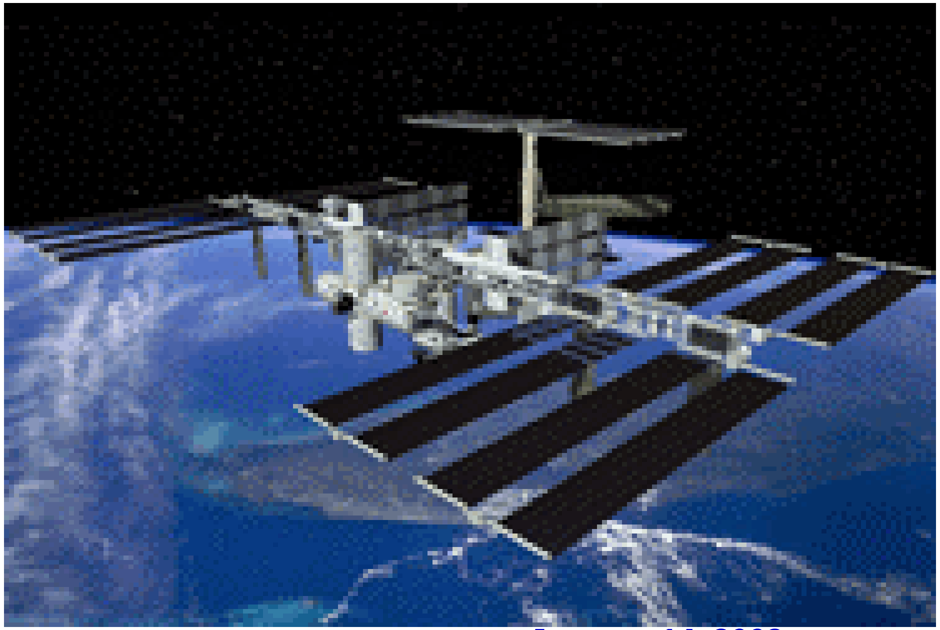
| | | | | |
|---|---|---|---|---|
| | 1530 | Nicola Muscettola | ARC | IDEA Autonomy Architecture |
| | 1615 | Benjamin W. Wah | UIUC | Stochastic Anytime Planning |
| | 1630 | Danel Gaines | JPL | Integrated Resource and Path Planning |
| | 1645 | Forest Fisher | JPL | Integrated Planning and Execution |
| | 1770 | Daniel S. Weld | UW | Contingent Planning and Execution |

# Project Summaries: Planning and Execution 4-05-02

| | | | | |
|---|---|---|---|---|
| | 945 | Ari K. Jónsson | ARC | Constraint-based Planning |
| | 1000 | Kanna Rajan | ARC | Mixed-Initiative Activity Planning |
| | 1015 | Jeremy Frank | ARC | SOFIA Scheduling |
| | 1100 | Rich Washington | ARC | Onboard Rover Autonomy |
| | 1115 | Subbarao Kambhampati | ASU | Partial-Order Temporal Planning |
| | 1130 | David E. Smith | ARC | Concurrent Contingency Planning |
| | 1145 | Benjamin D. Smith | JPL | Combinatorial Optimization Planning |
| | 1315 | Issa Nesnas | JPL | Rover Autonomy Architecture |

# Model-based Fault Protection

- Develop methods for detecting, diagnosing and reacting to mission events through the use of explicit models of hardware and software components.
- Model-based specification of system behavior at the component level, rather than the system level.



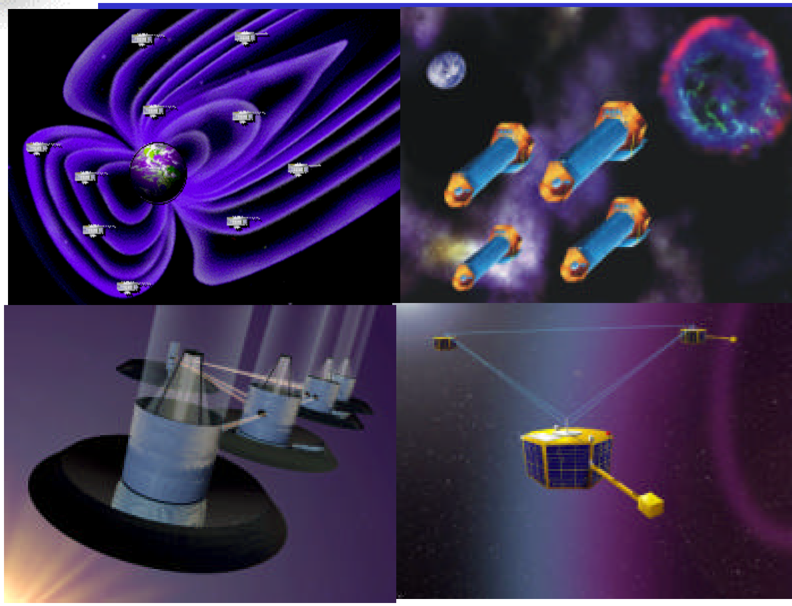
*Research Challenges:*

- Probabilistic methods for reasoning about complex systems
- Reasoning at different levels of abstraction
- Combined qualitative reasoning and quantitative parameter estimation
- Model-based execution systems with tighter guarantees on response time for fault protection
- Representation languages for modeling complex systems

# Model-based Fault Protection
# 4-05-02

| | | | | |
|---|---|---|---|---|
| | 1330 | Mark Shirley | ARC | L2 Diagnostic Agent/Skunkworks |
| | 1400 | Richard Dearden | ARC | Probabilistic Hybrid Fault Detection |
| | 1415 | Gautam Biswas | Vanderbilt | Fault-Adaptive Control |
| | 1430 | Hamid R. Berenji | ARC | Soft Computing for Fault Monitoring |
| | 1445 | Hamid R. Berenji | ARC | Team Coordination Strategies |
| | 1530 | David Watson | APL | Model-based Reactive Control |
| | 1545 | Brian C. Williams | MIT | Hybrid Health Management and Control |

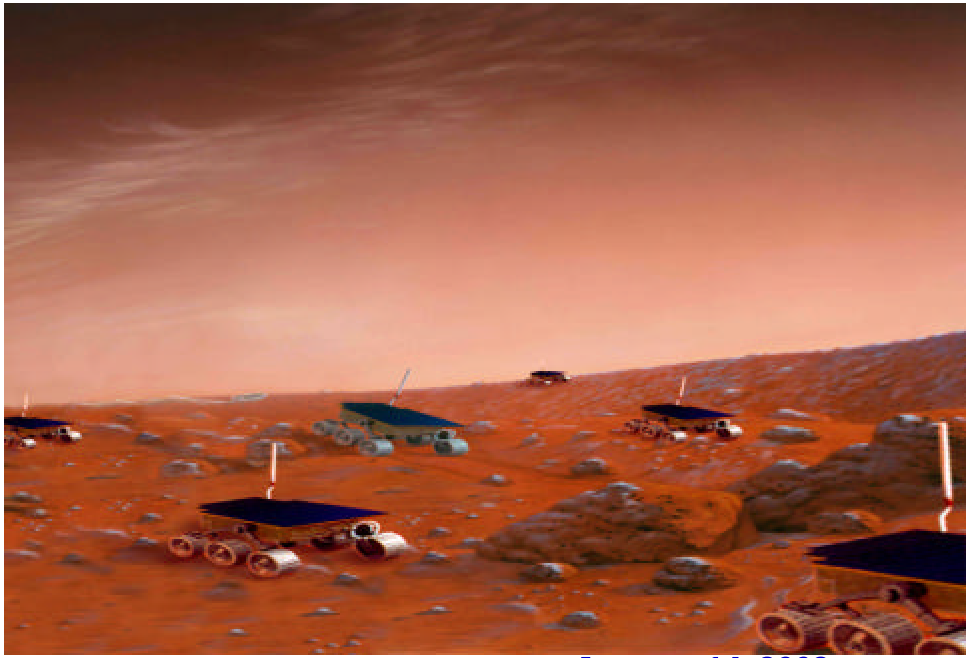
# Agent Architectures and Distributed Autonomy



•Develop capabilities that allow autonomous systems to coordinate activities in order to achieve a common goal.
•Develop techniques for controlling and coordinating multiple-asset missions.

## Research Challenges

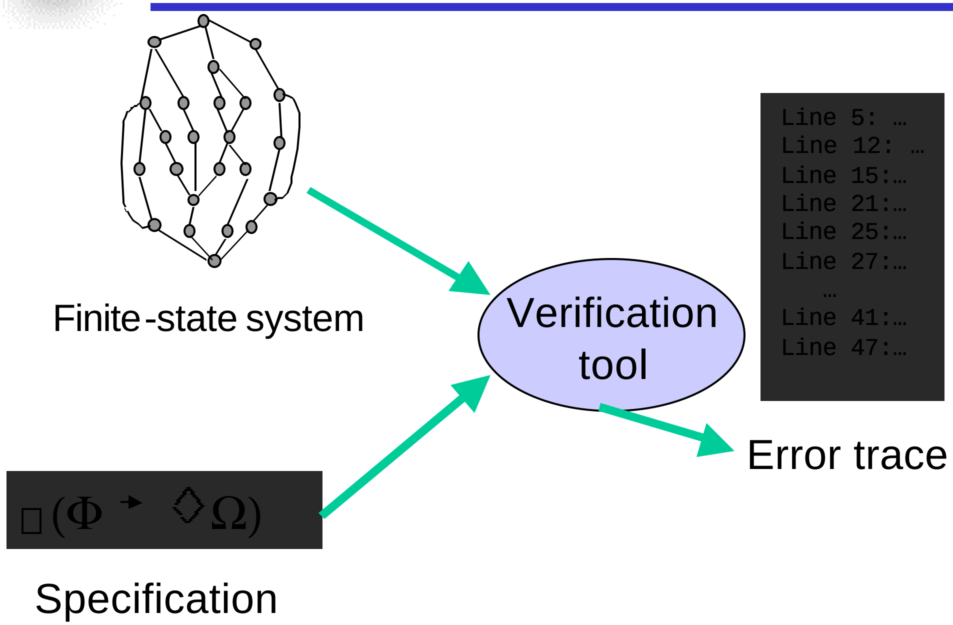
- Low-cost, scalable ground operations for multiple-asset missions.
- Planning and scheduling to enable coordinated operations
- Low-bandwidth approaches to onboard coordination.
- Ad hoc networking of existing satellites
- Collective fault detection, isolation and recovery.



# Project Summaries: Distributed Autonomy and Architectures 4-4-02

| | | | | |
|---|---|---|---|---|
| | 1330 | David Gaines | JPL | Onboard Scientist for Multi-Rover Science Investigation |
| | 1345 | Frank Kirchner | Northeastern | Team-Oriented Robotic Exploration |
| | 1400 | Dani Goldberg | CMU | Multi-Rover Coordination |
| | 1415 | Anthony Barrett | JPL | Team Sequence Execution |
| | 1430 | Anthony Barrett | JPL | Continual Team Planning |

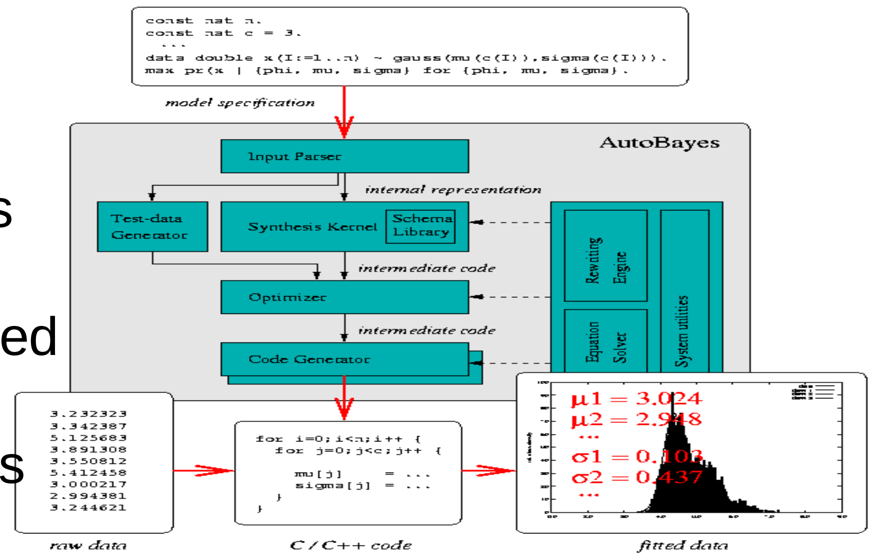
# Automated Software Engineering for Autonomy




- Build high-assurance software generators that target autonomy capabilities
- Create/adopt standards for software Integration of autonomy components
- Develop verification methods at different levels of granularity
- Methods for verifying software that adapts and learns

Research Challenges:

- Verification Technology Addressing Combinatorial Behavior of Autonomous Systems
- Verification Technology for Model-based Autonomy
- Integration of Verification Technologies Including Testing for Autonomy



# Automated Software Engineering for Autonomy 4-06-02

| | | | | |
|---|---|---|---|---|
| | 900 | Michael Lowry | ARC | State Estimation Program Synthesis |
| | 915 | Michael Lowry | ARC | Autonomy Verification and Validation |
| | 930 | Jonathan Whittle | ARC | Design Level Synthesis |
| | 945 | Bernd Fischer | ARC | AutoBayes |
| | 1000 | Chitta Baral | ASU | Agent Development and Verification |
| | 1015 | Dimitra Giannakopoulou | ARC | Modular Verification of Autonomous Systems |

# Other AR Workshop Highlights

- AR/IDU joint sessions
  - James Bellingham, Monterrey Bay Aquarium, (Wed. Banquet)
  - Dan Cooke, Texas Tech University (Thurs. Banquet)
  - Butler Hine and others (Friday Wrap-up Session)
- Mission autonomy infusion
  - James Crawford, ARC (Thurs. 0900)